Economy and Environment Program
for Southeast Asia
Tanglin PO Box 101
Singapore 912404
Phone: (65) 6831-6854
Fax: (65) 6235-1849
E-mail: eepsea@idrc.org.sg
Web site: www.eepsea.org

RESEARCH REPORT

NO. 2003-RR3

Air Quality Impacts of Increased Use of Indigenous Fuels for Power Generation in the Philippines

Elvira M. Orbeta
Resources, Environment and Economics Center for Studies (REECS), Suite 405, The Tower at Emerald Square, J. P. Rizal cor. P. Tuazon Sts., Project 4, Quezon City 1109, Philippines.

(eorbeta@mozcom.com, eorbeta@gate.pids.gov.ph)

This report assesses the environmental and health impacts of the development of indigenous and renewable energy sources in the Philippines. It finds that, over the period 2001-2011, such developments would result in less air pollution than a scenario in which only current energy sources are developed. The report also finds that, whatever energy sources are used, the planned increase in generating capacity in the country will result in increases in overall levels of air pollution. Local coal is singled out as a particularly polluting energy source. Overall the report recommends a number of pollution reduction initiatives including improved pollution monitoring and the promotion of energy efficiency.

Published by the Economy and Environment Program for Southeast Asia (EEPSEA)
Tanglin PO Box 101, Singapore 912404 (www.eepsea.org)
tel: +65-6235-1344, fax: +65-6235-1849, email: eepsea@idrc.org.sg

EEPSEA Research Reports are the outputs of research projects supported by the Economy and Environment Program for Southeast Asia. All have been peer reviewed and edited. In some cases, longer versions may be obtained from the author(s). The key findings of most *EEPSEA Research Reports* are condensed into *EEPSEA Policy Briefs*, available upon request. The Economy and Environment Program for Southeast Asia also publishes *EEPSEA Special Papers*, commissioned works with an emphasis on research methodology.

National Library of Canada cataloguing in publication data

Main entry under title :

Air quality impacts of increased use of indigenous fuels for power
generation in the Philippines

(Research report, ISSN 1608-5434, 2003-RR3)
Co-published by the International Development Research Centre.
Includes bibliographical references.
ISBN 1-55250-035-7

1. Electric utilities – Environmental aspects – Philippines.
2. Coal-fired power plants – Environmental aspects – Philippines.
3. Air quality – Philippines.
I. Orbeta, Elvira M.
II. Rufo, Carlito M.
III. Economy and Environment Program for Southeast Asia.
IV. International Development Research Centre (Canada)
V. Series: Research report (Economy and Environment Program for
Southeast Asia) ; 2003-RR3.

TD888.P76A3 2003 333.793’2’09599 C2003-980086-5

Air Quality Impacts of Increased Use of Indigenous Fuels for Power Generation in the Philippines

Elvira M. Orbeta and Carlito M. Rufo, Jr.

January, 2003

Comments should be sent to: Elvira M. Orbeta, Resources, Environment and Economics Center for Studies, Inc. (REECS), Suite 405, The Tower at Emerald Square, J. P. Rizal cor. P. Tuazon Sts., Project 4, Quezon City 1109, Philippines.

Tel. Nos. (632) 439-6617/439-6617; Fax No. (632) 438-8858

Email: eorbeta@mozcom.com, eorbeta@gate.pids.gov.ph

EEPSEA was established in May 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Lao PDR, China, Papua New Guinea and Sri Lanka.

EEPSEA is supported by the International Development Research Centre (IDRC); the Swedish International Development Cooperation Agency (Sida); and the Canadian International Development Agency (CIDA).

EEPSEA publications are also available online at http://www.eepsea.org.

ACKNOWLEDGEMENTS

We would like to thank everyone who made this study possible: EEPSEA for providing the research grant to the Resources, Environment and Economic Center for Studies, Inc. (REECS); Dr. David Glover, Program Director, and Dr. Herminia Francisco, Assistant Program Director, to whom this study was presented, for their valuable comments and recommendations; Dr. David James, for the invaluable comments, guidance, and encouragement; Dr. Mohan Munasinghe, Dr. Benoit Laplante, Dr. Dale Whittington, Dr. Cielito Habito, Dr. Le Quy An and participants of three separate EEPSEA Workshop Groups chaired by Dr. David Glover and Dr. Herminia Francisco; the management and staff of the Department of Energy particularly Usec. Cyril del Callar, Mr. Heruela, Ms. Cabacang, Thelma Ejercito, Gerry Austria, Maripaz de Leon; the management and staff of DOE Regions 7 and 11; the management and staff of the NPC and IPP power plants visited, especially the plant managers and engineers for facilitating the plant visits and providing the information required by the study; Emily and Greg of NPC; PAG-ASA, NAMRIA and EMB personnel, for their assistance in data gathering; and Rogelio Moncayo for providing research assistance. We also like to thank Babes, Abby, Susan, Cora, Bates, Eugene, the REECS staff, and members of our families for their loving support and understanding. Most of all, we thank God for making all things possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

AIR QUALITY IMPACTS OF INCREASED USE OF INDIGENOUS FUELS FOR POWER GENERATION IN THE PHILIPPINES

Elvira M. Orbeta and Carlito M. Rufo, Jr.

EXECUTIVE SUMMARY

The power industry of the Philippines, a government monopoly until the passage of the Electric Power Industry Reform Act in 2001, has had a particularly troubled history. Power sector reform has been extensively studied but less attention has been given to its environmental impact. This study assessed the air quality impact and the incremental benefits of increased use of indigenous energy resources for power generation in the Philippines during the period 2002-2011 – in other words, a "high indigenous" scenario, relative to the base case or "business as usual" scenario. In particular, the study quantified the likely changes in the level and spatial pattern of emissions from power generation and valued the incremental benefit of operating four coal-fired power plants under a high indigenous scenario. Based on the power supply projections, a high indigenous scenario envisioned in the 2002-2011 Philippine Energy Plan is projected to generate significant incremental impact in air quality, particularly in Luzon, relative to the base case.

Changes in the level and spatial pattern of emissions from power generation were estimated using a rapid assessment approach. The incremental benefit was valued using a damage function approach focusing on four coal-fired power plants in Luzon, which together account for a significant share of the country's coal-based and total generating capacity. The approach involved modeling the changes in ambient concentrations of PM_{10}, SO_2 and NO_2, determining the incremental health effects and valuing these in economic terms. The study focused on adverse health effects using dose-response functions established in other studies and economic values based on the benefit transfer technique.

Our results show significant reductions in incremental emissions in the high indigenous scenario, compared to the base case (business as usual) scenario. Reduction is largest for SO_2 and in Luzon. Luzon will remain the major source of PM_{10}, SO_2 and NO_2 emissions despite the declining share in annual emissions. Reductions in Luzon are matched by emission increases, particularly SO_2, in Visayas and Mindanao. However, both scenarios involve increases of nearly 10% a year in power generation and thus significant increases in emissions and health damages. In both scenarios, emissions will be markedly higher in 2011 than in 2000. Increased use of indigenous fuels, except local coal, generated incremental emission reduction.

The total incremental benefit of operating four coal-fired power plants under a high indigenous scenario is negligible. Incremental benefit, measured in terms of reductions in adverse health effects, is associated mainly with reductions in SO_2 and varied widely among the four power plants. Although negligible, the incremental benefit far outweighs the cost of shifting to cleaner fuel.

The study finds that substituting indigenous fuels, as envisioned in the Philippine Energy Plan, would on the whole result in fewer emissions compared to a business as

usual scenario. Since even the most favorable scenario assessed here will result in significant increase in emissions, we recommend that: a) incremental emission monitoring and control efforts by government and generating firms be geared at PM_{10} and SO_2 emissions in Luzon; b) existing policies on the use of local coal for power generation be reviewed; c) a review of the Clean Air Act and its implementing rules and regulations be done to make it more responsive to the needs of a more competitive power sector; and d) policies to encourage energy conservation should also be pursued.

1.0 INTRODUCTION

The power industry of the Philippines – until recently a government monopoly –has been plagued by a history of problems. In the early 1990s, the country suffered chronic power outages; these contributed to economic stagnation and widespread impatience with the government of the day. In 2001, the Arroyo government implemented RA 9136 otherwise known as the Electric Power Industry Reform Act (EPIRA). Its intention was to improve both economic efficiency and environmental performance by privatizing some elements of the system, changing tariffs, and promoting greater use of environment-friendly indigenous energy sources and systems as well as greater electricity conservation. To encourage the use and exploitation of indigenous energy sources such as natural gas and renewable energy sources such as hydropower, geothermal, solar thermal, biomass, and wind power, lower royalties, returns and taxes is collected for the exploitation of all indigenous sources of energy. Power rates from all indigenous sources of energy shall also be reduced to ensure lower rates for end-users.

Power sector reform has been extensively studied in many countries. The environmental impacts of such reform, however, have so far received much less attention. Hagler Bailly (1998) noted that for any given level of demand and fixed set of environmental policies, the effect of restructuring air emissions will depend on a number of factors, such as the extent of input substitution or what happens to the mix of fuels and technologies used to generate electricity. A scenario where entry of zero-emitting but expensive energy sources such as renewables is not favored by restructuring implies increased generation from relatively cheaper sources of electricity such as old coal-fired or under-utilized facilities and consequently increased air emissions. The incentive to improve plant operations and fuel efficiency with competition, however, gives an offsetting effect. A scenario favoring renewable energy sources and use of highly efficient and low-emitting gas-combined cycle turbines creates an incentive to switch from coal to gas-fired generation thus reducing emissions. The prospects for renewables to penetrate electricity markets, however, may be low mainly because of their relatively high cost as experienced by countries such as the United Kingdom and the United States. Other studies have also indicated that restructuring can have potential negative environmental impacts, increasing nitrogen oxides (NOx) and carbon monoxide (CO_2) emissions, particularly in areas surrounding relatively cheap sources of energy such as coal-fired power plants (Palmer and Burtraw 1996; Congressional Research Service 1998; Burtraw et al. 2000).

The 2002-2011 Philippine Energy Plan (DOE 2001) adopts as a policy the restructuring of the power sector to ensure efficiency and reliability in supply and competitive pricing of electricity for sustained economic growth as well as to ensure consumer choice. It envisions two major scenarios – the base case scenario or the business as usual scenario which assumes the continuance of existing policies and power expansion programs prior to the reform; and the indicative scenario- a high indigenous scenario- which undertakes increased development and utilization of indigenous and new and renewable energy resources. The latter was simulated to address the issue of energy security and the impact of power generation on the environment.

There is reason to believe that a high indigenous scenario will generate significant incremental environmental impacts, particularly in Luzon, based on the Department of Energy (DOE) power supply projections (DOE 2001). Indigenous, new and renewable energy resources-based generating capacities under the high indigenous scenario is projected to reach 15,604 MW or 71% of the total compared with 37% under the base case. Luzon which accounted for 86% of the total fossil-based and 95% of coal-based generating capacity as of 2000, on the other hand, is projected to decline with the retirement of old oil-based generating capacities and the development of natural gas and other indigenous resources during the planning period 2002-2011.

The high indigenous scenario is expected to increase self-sufficiency in energy sources from 49% to 84% by 2011. This increase in self-sufficiency will come about with the intensification of the development and use of indigenous fuels and less dependence on imported fuel. However, the indigenous fuels that will replace oil include some that are relatively clean (like geothermal power) and others that are relatively dirty (like coal). A priori, the net impact on the emission of pollutants is not obvious.

The purpose of this study, therefore, is to assess the air quality impacts and the incremental benefits of increased use of indigenous energy resources for power generation in the Philippines during the period 2002-2011. In particular, the study intends to: (a) quantify the likely changes in the level and spatial pattern of emissions from power generation under a high indigenous scenario and (b) value the potential incremental benefits of a high indigenous scenario.

A rapid assessment approach was used to estimate the changes in the level and spatial pattern of emissions from power generation in the country under the high indigenous scenario relative to the base case. To get an estimate of the value of the incremental benefit of a high indigenous scenario, a damage function approach was used focusing on four coal-fired power plants, two each in the north and south of Luzon, which together accounted for a significant share of the country's coal-based and total generating capacity. The approach involved modeling the changes in ambient concentrations of PM_{10}, SO_2 and NO_2, determining the incremental health effects, and valuing these in economic terms. The study focused on adverse health effects, using dose-response functions established in other studies and economic values based on the benefit transfer technique.

The remainder of the report is organized as follows: Section 2 provides a background on the basic features of the new electric power industry and profile of the power supply sector as of 2000. Sections 3 and 4 describe the scenarios analyzed and the methodology used, respectively. Section 5 discusses the results while Section 6 gives the conclusion and recommendations of the study.

2.0 BACKGROUND

2.1 The New Electric Power Industry Structure

Prior to the implementation of the industry reform, the National Power Corporation (NPC) - the largest government-owned and controlled corporation in the country - monopolized power generation until 1987. This was when private sector generators or independent power producers (IPPs) were allowed to participate in the building and operation of generating plants in response to signs of the power crisis (World Bank 1997). NPC generated electricity with its own plants and bought from IPPs through power purchase agreements or energy conversion agreements and then sold to distributors and directly connected large industries at regulated wholesale price. Other IPPs were allowed to generate and sell directly to distributors and large industries. NPC also monopolized transmission. Private investor-owned distributors such as the MERALCO, some local government units and rural electric cooperatives sell electricity directly to end-users. The Energy Regulatory Board regulated the retail price of electricity charged by distributors. Electricity price was bundled or not broken down into its cost components. Thus, subsidies and other costs that can be avoided with improvements in efficiency and reliability were not reflected.

RA 9136 introduced the necessary policy and structural reforms to make the industry more competitive. The new electric power industry consists of four sectors, namely, generation, transmission, distribution and supply (Figure 1). Below are the basic features of the reformed industry.

1. Power generation is no longer considered a public utility operation and shall be competitive and open. It may be undertaken by any person or entity engaged or will be engaged in power generation. The generation assets of NPC including the IPP contracts except for the assets used for missionary electrification[1] shall be privatized. NPC may generate and sell electricity only from the unsold generating assets and IPP contracts of the PSALM Corporation[2].

2. Transmission of electricity is a regulated common electricity carrier business. Access to transmission and distribution systems by all industry participants shall be open and non-discriminatory. The National Transmission Corporation (TRANSCO), created under RA 9136 and owned by the PSALM Corporation, assumes all the transmission functions and authority of the NPC.

3. Distribution of electricity is also a regulated common electricity carrier business. It may be undertaken by private distribution utilities, cooperatives, local government units and other duly authorized entities. A Grid Code and a Distribution Code govern the behavior of participants in the transmission and distribution sub-sectors.

---

[1] Missionary electrification is "the provision of generating facilities in areas not connected to the main grid and areas where no private entities are able or willing to provide electric service at affordable cost without subsidy" (DOE 2001). This is a function of the NPC performed through the Small Power Utilities Group (SPUG) as mandated by RA No. 6395.

[2] PSALM is a government-owned and controlled corporation, created pursuant to RA 9136 to assume ownership of all existing NPC generation assets, liabilities and IPP contracts, real estate, and all other disposable assets. It manages the sale, disposition and privatization of NPC.

4. Retail supply[3] of electricity shall be open and competitive within three years.

5. A wholesale electricity spot market operated under TRANSCO was established within a year.

6. Tariff rates and functions are unbundled. Transmission rate is unbundled from generation rate to reflect the respective costs of delivering each service. Similarly, distribution-wheeling charge is unbundled from the retail rate. Electricity rates include a universal charge to cover: (a) stranded costs[4], (b) missionary electrification, (c) amount required to equalize taxes and royalties applied to indigenous or renewable sources of energy vis-à-vis imported energy fuels, (d) environmental charge equal to Pesos 0.0025 (USD 0.0000489) per kWh for watershed rehabilitation and management, and (e) all forms of cross-subsidies[5] for a period not exceeding three years. Industry participants are required to separate their business activities and rates functionally and structurally consistent with the four sectors identified in the law. The Energy Regulatory Commission regulates the tariff rates.

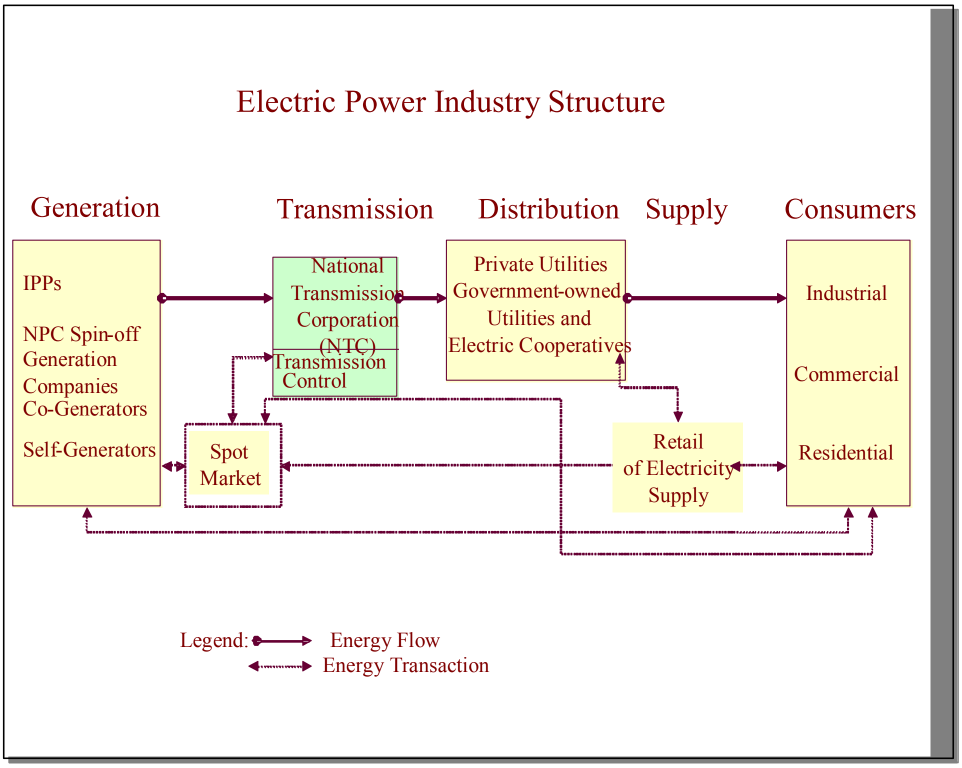


Figure 1. Electric Power Industry Structure

[3] Retail supply involves "the sale, brokering, marketing or aggregation of electricity to end-users by a party other than a generator or a distributor in the franchise area of a distribution utility using the wires of the distribution utility concerned".
[4] Stranded costs refer to "the excess of the contracted costs of electricity under eligible contracts over the actual selling price of the contracted energy output of such contracts in the market" (RA 9136).
[5] Inter-grid, intra-grid and inter-class cross subsidies shall be removed not later than three years after implementation of the EPIRA.

2.2 Profile of the Power Supply Sector as of 2000

The country has significant wind, hydropower, geothermal and natural gas resource potential mostly in Luzon. The country ranks second to the US in terms of geothermal energy generation. Table 1 provides some information on the country's energy resources and power supply as of 2000.

Table 1. Energy Resource Potential and Power Supply Statistics as of 2000

Energy Resources Geothermal • 4,500 MW total resource potential (Luzon – 54%, Visayas – 38%; Mindanao – 8%) Hydropower • 9,150 MW total resource potential; 47% in CAR and Region IV in Luzon Coal • Imported; 2.3 billion MT potential resources in Semirara Island, Cagayan Valley and Zamboanga; can potentially supply coal-fired power plants (PP) with a total capacity of 700 MW Oil • Imported; potential oil production from discovered oil resources of 246 MMB in NW Palawan and 37.40 MMB in Mindoro-Cuyo basin	Natural Gas • Malampaya offshore gas field in Palawan in Luzon will start commercial production at an initial rate of 145 BCF; will fuel 3 baseload PP with a total capacity of 2,700 MW in Southern Luzon • Potential resource areas include Fuga Island and other offshore fields in Palawan, Maguindanao-Cotabato and Sulu in Mindanao, and Leyte and Cebu in Visayas New and Renewable Energy (NRE) • Significant wind (70,000 MW) and micro-hydro (average 28 MW/site identified) resource potential • Biomass – includes fuelwood, bagasse, charcoal and agriwaste
Generation Self-sufficiency level - 48.7% Generating capacity Total installed capacity - 13,264 MW • Oil-based – 39% • Coal – 29% • Hydro – 17% • Geothermal – 15% • Natural gas (NG) – negligible Geographic distribution • Luzon – 76% • Visayas – 12% • Mindanao – 12% Ownership: NPC – 68%; Private – 32%	***Transmission and substation*** Transmission lines (T/L) and substation (S/S) capability • 20,457 circuit-kilometers T/L • Luzon – 54%; Visayas – 19%; Mindanao – 27% • 27,606 million volt-amperes S/S *Distribution and Supply* Private sector (investor-owned distributors, some local government units and rural electric cooperatives)
Total capacity added in 2000: 1,578 MW • 1,000 MW natural gas-fired power plant (fueled by condensate, naptha and diesel until NG becomes available in 2002) • 470 MW coal-fired • 108 MW diesel-fired	Electricity sales: 36.6 TWh • Industrial sector – 36.1%; residential sector– 35.3%; commercial sector – 26.0%; others – 2.6% • Luzon – 76%; Visayas – 9%; Mindanao – 15%
Annual generation: 45.3TWh • Oil-based – 20%; Coal – 37%; Hydro – 17%; Geothermal – 26%; Natural gas – 0% • Luzon – 70%; Visayas – 17%; Mindanao – 13% • 8% of gross generation accounted for station use and transmission loss Pollution control measures (Please refer to Appendix 1.) Plants retired/scheduled for retirement - 1,020 MW (oil-based)	Electricity tariff rates: • Ave. (Pesos/kWh): 3.11 • Luzon – 3.34; Visayas – 3.22; Mindanao – 1.93, Small Island – 1.94

Sources: DOE 2001; Philippine Energy Plan 2002-2011; NPC 2000; 2000 Power Development Program; DOE Statistics as of December 2000.

Note: 44.19 Pesos = 1 USD

Table 2 shows a detailed distribution of the generating capacity by type, grid and ownership and the average rated capacity by type. Luzon accounted for 76% of the total installed generating capacity as of 2000. This consists of oil-based, coal, hydropower and geothermal power. Visayas and Mindanao accounted for 12% each - mainly geothermal and hydropower respectively, supplemented by oil-based power barges. Rated capacity per unit ranges from as low as 9 MW for diesel plants to as high as 600 MW for natural gas-based power plants. NPC owned 68% but operated only 32% of the total capacity. IPPs shared a significant role in the operation of NPC plants and of total generating capacity.

Table 2. Distribution of Generating Capacity by Type, Grid and Ownership as of 2000

Plant Type	*Generating Capacity by Grid (MW)*				*Rated Capacity/Unit (MW)*	*Ownership and Generation Share (%)*[1]		
	Luzon	*Visayas*	*Min-danao*	*Total*		*NPC*	*NPC-IPP*	*IPP*
Oil-based	4,193	443	566	5,202				
Diesel	71%	9%	19%	1,480	9 - 75	13	13	74
						10	*20*	*70*
Oil thermal	97%		3%	1,687[3]	200–350	38	62	
						50	*50*	
Gas turbine (GT)	85%	15%		435	55 - 70		15	85
							1	*99*
Combined cycle GT[2]	100%			1,600	300 -500	0	37	63
							100	
Coal	3,620	205	0	3,825	300–500	31	56	13
						36	*62*	*2*
Hydro	1,302	12	991	2,304	< 32;	88	8	4
					70 - 360	*93*	*4*	*3*
Geothermal	852	916	95	1,863	20 - 182	60	1	39
						56	*<1*	*43*
Nat. gas[2]	3			3	300- 600			100
Biomass								
Total	9,970	1,575	1,652	13,197				
Percent to Total	76%	12%	12%	100%				

[1] Based on installed capacity; includes only the power plants linked to the main grid; excludes about 67 MW generating capacity not connected to the main grid.

[2] A 1,040 MW CC/diesel power plants or 25% of oil-based capacity in 2000 will be fueled with natural gas starting 2002 and reclassified accordingly under natural gas.

[3] About 350 MW were retired before end of 2000.

Fossil-fired power plants represented 68% of total generating capacity as of 2000 (Table 2). Capacity is distributed as follows: 42% coal-fired and 58% oil-based. Rated capacity per unit ranges from as low as 9 MW for diesel to as high as 500 MW for coal. Sixty-one percent of existing coal and oil-based capacity is relatively new, i.e., less than five years old as of 2000 (Appendix 1). About 1,040 MW of oil-based capacity will be fueled with natural gas by 2002. About 1,905 MW of oil-based generating capacity mostly in Luzon are scheduled for retirement between 2002 and 2011 (DOE 2001). Stack heights range from 120 to 220 m for coal, 25 m for combined cycle, 40 to 80 m for diesel, and 90 to 212m for oil-thermal (Appendix 1). New coal-fired power plants are equipped with appropriate pollution control equipment consisting of electrostatic precipitators (ESP) for PM, flue gas desulfurization (FGD) equipment for SOx, and low NOx burners while old power plants have ESP or a bag house with wet scrubber. Oil-thermal plants have multicyclones. For existing diesel power plants or barges, emissions are controlled by the usage of low-sulfur fuel and proper maintenance of equipment. NPC owned all oil thermal plants and a significant share of the total coal capacity while IPPs owned a substantial share of the diesel, gas turbine and combined cycle gas turbines. IPPs accounted for a large share of the total fossil-based generation. Appendix 1 provides a plant level profile of the existing fossil-fired power plants as of 2000.

3.0 SCENARIOS ANALYZED

The study evaluated the DOE-simulated indicative scenario that favors the development and increased use of indigenous energy resources over the planning period 2002-2011 relative to the base case or the business as usual scenario. Annual averages were also compared with the levels in 2000 or prior to the power sector reform.

The *base case* and the *high indigenous* scenario are both based on the following key planning parameters: 6.0% average GDP growth rate; projected population of 79.5 million in 2002 and 93.3 million in 2011; average crude oil price of USD 25 per barrel; and an exchange rate pegged at 2001 level of Pesos 50 per USD 1. The scenarios support a projected electricity demand that grows at an average of 9.7% per year from 47.9 tegawatt-hours (TWh) in 2002 to 110.2 TWh in 2011.

The *base case* adopts the NEDA-generated low economic growth forecast and the base case scenario of the Power Development Plan (PDP) for the period 2002-2011 (DOE 2001), considered the most likely scenario. To meet the projected electricity demand, the scenario assumes continuation of existing policies and power expansion programs through the implementation of committed and indicative generation projects between 2002 and 2011. Committed projects consist of about 2,935 MW generating capacity mainly fueled by natural gas (Table 3). Generation from these projects together with those from existing capacity is considered adequate to meet the power demand until 2007. Indicative generation capacity is estimated at 9,440 MW. Total generating capacity by 2011 is 23,929 MW, 37% of which is based on indigenous resources.

The *high indigenous* scenario is consistent with the provisions of the EPIRA, which promotes the development of indigenous and renewable energy sources. It simulates the enhancement of existing policies and programs with the development and increased utilization of indigenous energy resources such as natural gas, local coal, hydro, geothermal resources and new and renewable energy sources for power generation. This scenario entails the construction of an additional 10,443 MW of identified indigenous energy resources-based generating capacity or a total of 13,378 MW including the committed projects (Table 3). Indigenous resource-based generating capacity is projected to reach 15,604 MW by 2011, representing 71% of the total capacity. The development and increased utilization of indigenous energy resources is intended to reduce the country's dependence on imported fuel for power generation. This will increase self-sufficiency level from 49% in 2000 to 72% under the base case and 84% under the high indigenous scenario in 2011.

The scenarios also took into account: (1) interconnection of Luzon, Visayas and Mindanao by 2005 based on the transmission and substation expansion plan aimed at unifying the Philippine grid for effective sharing of reserves; (2) implementation of the Philippine Gas Project; (3) optimal use of indigenous sources of energy; (4) support of the government's program under a new industry structure; (5) implementation of on-going and committed projects; (6) retirement of about 1,905 MW oil-based generating capacity; and (7) environmental standards set by the Clean Air Act. The potential gains from the implementation of energy efficiency improvement and demand side management programs were also considered. Table 3 summarizes the basic features of the two scenarios.

The projected generation mix reflects the government's policy to reduce dependence on imported fuels and increase the use of indigenous fuels particularly natural gas (Table 4). Luzon accounts for over 70% of the projected generation. Based on the DOE projections, Mindanao's own electricity supply will be insufficient starting 2005 until the end of the planning period. The deficit will decline from about 27% of its requirement in 2005 to about 11% by 2011. The Leyte-Mindanao interconnection in 2005 is intended to facilitate the flow of surplus generation from Luzon and the Visayas. Appendix 5 shows the incremental generation relative to the base for 2002-2011 under the high indigenous scenario.

Table 3. Description of Scenarios Analyzed

Item/Scenario	*Base Case (2002-2011)*	*High Indigenous (2002-2011)*
Self-sufficiency level	63% in 2002 72% in 2011	67% in 2002 84% in 2011
Generating capacity	As of 2002 – 13,459 MW Oil-based – 5,179 MW (38.4%) Imported coal – 3,225 MW (23.9%) Local coal – 600 MW (4.4%) Hydro – 2,521 MW (18.7%) Geothermal – 1,931 MW (14.3%) NG – 3 MW (negligible) Cumulative capacity by 2011: 23,929 MW *Indigenous – 8,790 MW (37%)* Local coal – 600 MW Hydro – 3,216 MW Geothermal – 1,931 MW NG – 3,003 MW Biomass – 40 MW *Imported – 5,699 MW (24%)* Oil-based – 2,379 MW Imported coal – 3,320 MW *Generic – 9,440 MW (39%)* Baseload – 56% Midrange – 16% Peaking – 28%	As of 2002 - same as base case Cumulative capacity by 2011: 21,998 MW *Indigenous – 15,604 MW (71%)* Local coal – 600 MW Hydro – 3,788 MW Geothermal – 2,901 MW NG – 7,378 MW (includes some existing oil- and coal-fired power plants converted to NG-fired) NRE – 587 MW *Imported – 6,394 MW (29%)* includes oil-based and imported coal – fired power plants *Others* – 350 MW (petcoke)

Additional capacity	Total (2002-2011) – 12,375 MW
	Committed – 2,935 MW (24%)
	• Imported coal – 200
	• Hydro – 695
	• NG – 2,000
	• NRE – 40
	Indicative – 9,440 MW (68%)
	• Baseload – 56%
	• Midrange – 16%
	• Peaking – 28%
	Geographic distribution
	• Luzon – 76%
	• Visayas – 14%
	• Mindanao – 10%
		Total (2002-2011) – 13, 378 MW
		• Committed – 2,935 MW (22%)
		• Indicative – 10,443 MW (78%)
		  • NG – 6,350; Geo – 970; Hydro – 1,266; Local coal – 920;
		  • NRE – 587
		    • Wind – 417; Biomass – 40; Coco-diesel – 50; Municipal solid waste – 50; Tidal – 30; Petcoke – 350
		
		Geographic distribution
		• Luzon – 83%
		• Visayas – 11%
		• Mindanao – 6%

Pollution control measures	New plants are assumed to meet the requirements of the Clean Air Act	New plants are assumed to meet the requirements of the Clean Air Act
Plants retired/scheduled for retirement	Total - 1,905 MW • coal-based – 105 • oil-based – 1,800 Luzon – 1,481 (78%) Visayas – 424 (22%)	Same as base case
Transmission lines (T/L) and substation (S/S) capability	• Completion of Leyte-Bohol inter-connection Stage 3 by 2003 (will connect Bohol to Leyte and the whole Visayan grid) • Interconnection of the Mindanao grid with the Luzon-Visayas grid in 2005 • up-rating of Leyte-Cebu, Leyte-Bohol, and Negros–Cebu T/L • T/L backbone development	Same as base case
Total savings from technology innovations and energy efficiency and conservation programs	Total – 68.5 million barrels of fuel oil equivalent (MMBFOE) • 2002 - 5.81 MMBFOE or 180 MW of deferred generating capacity equivalent (MWDGCE) • 2011 – 7.78 MMBFOE or 424 MWDGCE	Incremental savings were not determined

Source: DOE 2001. Philippine Energy Plan 2002-2011

Table 4. Shares of Power Generation by Energy Source and Location: Baseline and High Indigenous Scenarios, 2002 - 2011

Energy Source	*2000*	*2002*		*2005*		*2008*		*2011*	
	Actual	*Base*	*High Ind.*	*Base*	*High Ind.*	*Base*	*High Ind.*	*Base*	*High Ind.*
	Percentage (%)								
Coal	37	34	33	37	35	30	33	21	24
Oil-based	20	6	6	7	2	13	8	9	8
Natural gas	0	30	30	30	33	24	33	17	44
Hydropower	17	13	11	10	11	8	10	6	9
Geothermal	26	17	19	16	18	12	15	9	12
NRE	0	0	0	Neg.	0.4	Neg.	0.7	Neg.	0.9
Others	0	0	0	0	0	13	0.3	38	2
TOTAL (TWh)	45.3	51.6	51.7	64.8	65.4	86.0	85.9	116.2	114.4
Luzon	69	72	72	78	77	78	75	76	75
Visayas	17	16	16	13	16	12	15	13	14
Mindanao	14	12	12	9	7	10	10	11	11

Source: DOE, PEP 2002-2011; DOE Planning Dept.

4.0 METHODOLOGY

The study utilized the damage function approach to assess the incremental benefits of increased use of indigenous fuels for power generation during the 2002-2011 planning period or a high indigenous scenario. The approach involved five major steps, namely, (1) scenario specification (2) determination of changes in the level and spatial pattern of emissions (3) prediction of changes in ambient air quality (4) quantification of adverse health effects and (5) valuation of adverse health effects. These steps are described in detail below. Table 5 summarizes the procedure and provides a list of the data used and corresponding sources.

1. *Scenario specification*. The study adopted the base case and the high indigenous scenarios and the corresponding power generation projections for the planning period 2002-2011 of the Department of Energy.

2. *Determination of the changes in the level and spatial pattern of emissions*. A rapid assessment approach was used in estimating emissions from power plants located nationwide. The approach uses plant level data of electricity generation or fuel requirement as process rate and appropriate emission coefficients (Appendix 2) to generate emission estimates. The estimates took into account the pollution control in place. Plants constructed beyond 2000 were assumed to implement the necessary control measures to meet the environmental standards. The pollutants included those associated with fossil-based generation with local impact on the environment, namely, PM_{10}, SO_2 and NO_2 emissions. The assessment covered all power plants connected to the main or national grid[6]. The main grid consists of the Luzon, Visayas and Mindanao grids, serving the three

[6] Grid refers to the high voltage backbone system of interconnected transmission lines, substations and related facilities (RA 9136).

major island groups of the country. Changes in spatial pattern of emissions were determined by comparing incremental emissions by grid under various scenarios.

Valuation of the incremental adverse health effects in a high indigenous scenario focused on areas where changes in emissions could potentially be significant following a projected increase in generation, such as those surrounding the four major coal-fired power plants in Luzon. For these areas, the succeeding steps were undertaken.

3. *Prediction of changes in ambient air quality*. Air dispersion modeling was done to predict changes in ambient concentration of pollutants in areas surrounding major sources of emissions such as those surrounding the four coal-fired power plants in Luzon. The US-EPA ISCST390 air dispersion model was used. The model uses the following data as inputs: plant characteristics, data on plant operations and emissions monitoring, appropriate climatologic data, and topography of surrounding areas. Ambient concentration at a receptor was related to changes in emissions from all sources using a transfer coefficient (Tietenberg 1996). The coefficient indicates the constant change in concentration at the receptor per unit change in emissions from a source.

4. *Quantification of adverse health effects associated with changes in ambient concentrations of PM_{10}, SO_2 and NO_2*. Dose-response functions adopted from studies conducted in other countries (Appendix 3) were used to determine health outcomes such as incidences of mortality and morbidity effects associated with predicted changes in ambient concentrations of PM_{10}, SO_2 and NO_2. The study assumed a threshold level of zero since no threshold level has been identified yet for these pollutants. The size of the population at risk of exposure was derived using a 30-km radius impact area delineated using 1:50,000 topographic maps and 500 m x 500 m grid and census data for 1990 and 1995.

5. *Valuation of adverse health effects*. Economic values for relevant adverse health effects were applied using the benefit transfer method. This method assesses values by applying estimates of values of adverse health effects from completed studies in other locations such as the United States. For mortality effects, the unit values were based on willingness to pay (WTP) estimates taken from other countries and adjusted for differences in income levels and exchange rates. For the morbidity effects, local data on the cost of illness (COI) were used as much as possible. WTP estimate of the morbidity effects were derived by applying the typical ratio of WTP to COI reported in other studies. Appendix 4 shows the unit values applied.

Table 5. Methodology and Data Requirements

Steps	*Methodology*	*Data Requirements*	
		Type	*Source (s)*
1. Scenario specification	- Adopt DOE specification and projections	- Description of scenario and corresponding projections of generation and fuel requirement	DOE
2. Determination of the changes in the level and spatial pattern of emissions	- Rapid assessment method using US-EPA AP-42 emission factors - Focus on local pollutants such as PM_{10}, SO_2 and NO_2 - Cover all air-emitting power plants connected to the main grid within the period 2000 - 2011	- Plant level data on capacity, fuel characteristics and annual consumption, gross energy generation, and air pollution control equipment - Emission factors	- DOE, NPC, EMB – DENR - EIA documents - US-EPA 1995
3. Prediction of changes in air quality	- Air dispersion modeling for major sources of emissions particularly the four coal-fired power plants in Luzon - use US-EPA ISC390 model - verify data used through plant visit	- Data required for air dispersion modeling (e.g., plant characteristics, operations and emissions monitoring data, climatologic data, and topographic data) - topographic maps	- PAGASA 2000 - National Mapping and Resource Information Authority (NAMRIA) - US-EPA 1995
4. Quantify adverse health effects associated with PM_{10}, SO_2 and NO_2 emissions	- Use dose-response functions	- Predicted ambient concentration - 1:50,000 topographic maps covering 30 km-radius for each plant - Population data by age group at municipal level - Dose-response coefficients	- Air dispersion modeling results - NAMRIA - National Statistics Office 1990 and 1995 - Ostro 1994, 1996
5. Valuation of adverse health effects	Benefits transfer approach	- Unit values of health impacts based on WTP and COI estimates - Local wages and cost of medication	- Rowe *et al* 1995 - US-EPA 1997 - NSCB – Phil. Stat. Yearbook - Dept. of Health

5.0 RESULTS AND DISCUSSION

5.1 Changes in Level and Spatial Pattern of Air Emissions

5.1.1 Changes in Level of Air Emissions

A high indigenous scenario is associated with significant reductions in air pollutant emissions from power generation, particularly in Luzon between 2002 and 2011, relative to the base case. Projected reductions are attributed to the increased utilization of indigenous resources such as natural gas, hydro, geothermal, and new and renewable energy resources displacing oil-based power generation. Incremental emission reduction is largest for SO_2 – 41% annually compared with 38% for PM_{10} and 34% for NO_2 (Tables 6 to 8). Average annual incremental reduction is about 128,840 metric tonnes (t) for SO_2, 5,237 t for PM_{10} and 34,647 t for NO_2 (Tables 9 to 11). Average annual emissions from coal-based power generation exceed those from oil-based generation.

The increased use of local coal for power generation under the high indigenous scenario is projected to generate an incremental increase in annual emissions posing harm to the environment. Incremental increase in emissions is estimated at 167 t for PM_{10}, 9,767 t for SO_2, and 3,701 t for NO_2 annually (Tables 9 to 11).

Average annual emissions under the high indigenous scenarios exceed the 2000 emission estimates. Average annual emissions are higher by 58% for PM_{10}, 23% for SO_2 and 67% for NO_2 as generating capacities, particularly coal-based capacities, are maximized with additional coal and oil-based capacities added to meet a growing demand (Tables 6 to 8). These incremental increases are relatively low compared to the increments under the base case estimated at 153% for PM_{10}, 108% for SO_2, and 151% for NO_2.

Table 6. Estimated Average Annual PM_{10} Emissions[1] from Power Generation by Type and by Grid: 2000, Base Case and High Indigenous Scenario

Type	*Luzon*			*Visayas*			*Mindanao*			*Philippines*		
	2000	*Base Case*	*HI*	*2000*	*Base Case*	*HI*	*2000*	*Base Case*	*HI*	*2000*	*Base Case*	*HI*
PM_{10}	*2,993*	*5,224*	*3,186*	*101*	*1,515*	*952*	*224*	*1,670*	*1,098*	*3,318*	*8,410*	*5,237*
Coal	2,043	2,603	2,602	47	110	262	0	119	117	2,091	2,832	2,981
Local	170	215	286	-	-	96	-	-	-	170	215	382
Imported	1,873	2,388	2,316	47	110	166	-	119	117	1,920	2,616	2,599
Oil-based	950	1,319	584	54	668	527	224	1,469	975	1,227	3,456	2,086
Diesel	420	792	357	54	668	527	224	1,469	975	697	2,930	1,859
Oil thermal	399	424	198	-	-	-	-	-	-	399	424	198
Gas turbine	3	0	0	0	0	0	-	0	-	3	1	0
Comb. cycle	127	102	29	-	-	-	-	-	-	127	102	29
Others		1,302	0		737	163	-	82	6	-	2,122	169

[1] Units in metric tonne

Table 7. Estimated Average Annual SO_2 Emissions[1] from Power Generation by Type and by Grid: 2000, Base Case and High Indigenous

Type	*Luzon*			*Visayas*			*Mindanao*			*Philippines*		
	2000	*Base Case*	*HI*	*2000*	*Base Case*	*HI*	*2000*	*Base Case*	*HI*	*2000*	*Base Case*	*HI*
SO_2	*171,272*	*269,991*	*136,932*	*4,674*	*38,909*	*38,768*	*11,436*	*81,382*	*55,092*	*187,382*	*390,282*	*230,792*
Coal	80,895	97,649	97,592	2,299	5,451	14,410	-	6,950	6,886	83,193	110,050	118,867
Local	9,969	12,624	16,764	-	-	5,630	-	-	-	9,969	12,624	22,393
Imported	70,925	85,025	80,828	2,299	5,451	8,780	-	6,950	6,886	73,224	97,426	96,474
Oil-based	90,377	97,222	39,340	2,375	29,592	23,141	11,436	71,726	48,070	104,189	198,540	110,551
Diesel	18,631	31,810	14,483	2,368	29,521	23,133	11,436	71,672	48,070	32,436	133,033	85,685
Oil thermal	31,861	33,875	15,794	-	-	-	-	-	-	31,861	33,875	15,794
Gas turbine	695	22	1	7	71	8	-	54	-	702	147	9
Comb. Cycle	39,190	31,515	9,063	-	-	-	-	-	-	39,190	31,515	9,063
Others		75,120	0		3,866	1,217	2,500	2,707	157	-	81,693	1,374

[1] Units in metric tonne

Table 8. Estimated Average Annual NO_2 Emissions[1] from Power Generation by Type and by Grid: 2000, Base Case and High Indigenous

Type	*Luzon*			*Visayas*			*Mindanao*			*Philippines*		
	2000	*Base Case*	*HI*	*2000*	*Base Case*	*HI*	*2000*	*Base Case*	*HI*	*2000*	*Base Case*	*HI*
NO_x	*38,459*	*69,440*	*45,378*	*2,287*	*19,621*	*14,358*	-	*19,656*	*12,468*	*43,247*	*108,716*	*72,204*
Coal	28,411	39,413	39,585	1,686	3,814	6,635	-	1,448	1,431	30,098	44,676	47,651
Local	3,778	4,784	6,353	-	-	2,133	-	-	-	3,778	4,784	8,486
Imported	24,633	34,630	33,233	1,686	3,814	4,501	2,500	1,448	1,431	26,320	39,892	39,165
Oil-based	10,048	13,649	5,783	601	7,481	5,887	2,500	16,411	10,888	13,149	37,545	22,559
Diesel	4,688	8,849	3,992	599	7,463	5,886	-	-	-	7,787	32,723	20,766
Oil thermal	2,182	2,302	1,073	-	-	-	-	5	-	2,182	2,302	1,073
Gas turbine	74	2	0	2	18	2	-	-	-	76	25	2
Comb. Cycle	3,104	2,496	718	-	-	-		-	-	3,104	2,496	718
Natural gas		8	9		-	-		-	-		8	9
Others		16,370	0		8,325	1,836		1,792	149		26,487	1,985

[1] Units in metric tonne

The projected reduction in air emissions between 2002 and 2004 (Tables 9 to 11) coincides with the scheduled operation of three baseload natural gas-fired power plants starting 2002, decommissioning of about 400 MW oil-based capacity, and increased utilization of hydro and geothermal power. These activities are in support of the government's policies to boost the development and utilization of indigenous and renewable energy resources and reduce dependence on imported fuel such as coal and oil used for electric generation and explicit plans to phase out old oil-thermal power plants. Between 2005 and 2010, projected increases in emissions coincide with the planned commissioning of additional fossil-based generating capacity. The projected decline in emissions in 2011 coincides with the scheduled retirement of about 850 MW oil-based and 105 MW coal-fired generating capacity[7].

Table 9. Incremental PM_{10} Emissions[1] under the High Indigenous Scenario: Philippines, 2002-2011

Type	*PM_{10} (in metric tonnes)*				
	2002	*2005*	*2008*	*2011*	*Average*
Coal	-17	-53	362	355	160
Local	0	74	310	386	167
Imported	-17	-127	52	-32	-7
Oil-based	116	-1,553	-1,903	-1,462	-1,307
Diesel	116	-1,312	-1,475	-1,462	-1,085
Oil thermal	0	-241	-428	0	-222
Others	0	-49	-1,918	-7,306	-1,923
TOTAL	*99*	*-1,655*	*-3,459*	*-8,414*	*-3,065*

[1] Relative to the Base Case

[7] The retired plants shall have been 20 to 36 years in service by retirement date.

Table 10. Incremental SO_2 Emissions[1] under the High Indigenous Scenario: Philippines, 2002-2011

Type	*SO_2 (in metric tonnes)*				
	2002	*2005*	*2008*	*2011*	*Average*
Coal	-5,159	-2,158	21,294	22,665	9,183
Local	-3	4,341	18,186	22,659	9,767
Imported	-5,156	-6,499	3,109	6	-584
Oil-based	4,062	-77,283	-78,996	-37,217	-57,912
Diesel	4,036	-58,039	-44,777	-37,217	-40,177
Oil thermal	26	-19,243	-34,219	0	-17,735
Others	0	-224	-82,644	-310,439	-80,110
TOTAL	*-1,097*	*-79,665*	*--140,346*	*-324,991*	*-128,612*

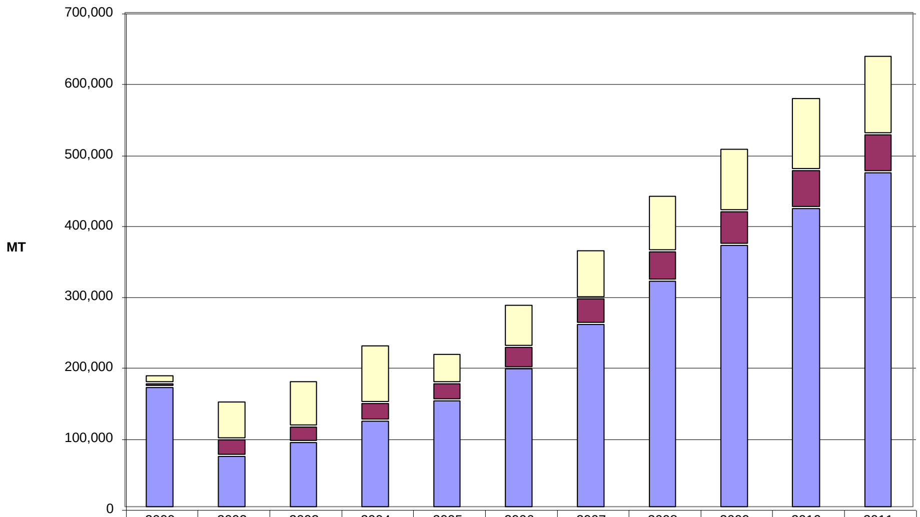
[1] Relative to the Base Case

Table 11. Incremental NO_2 Emissions[1] under the High Indigenous Scenario: Philippines, 2002-2011

Type	*NO_2 (in metric tonnes)*				
	2002	*2005*	*2008*	*2011*	*Average*
Coal	-264	-1,013	7,342	7,295	3,128
Local	-1	1,645	6,891	8,587	3,701
Imported	-263	-2,658	450	-1,292	-573
Oil-based	1,296	-15,965	-19,432	-17,341	-13,654
Diesel	1,295	-14,658	-17,107	-17,341	-12,449
Oil thermal	2	-1,307	-2,325	0	-1,205
Natural gas	0	0	1	8	2
Others		-551	-23,604	-93,461	-24,122
TOTAL	*1,032*	*-17,530*	*-34,300*	*-101,300*	*-33,855*

[1] Relative to the Base Case

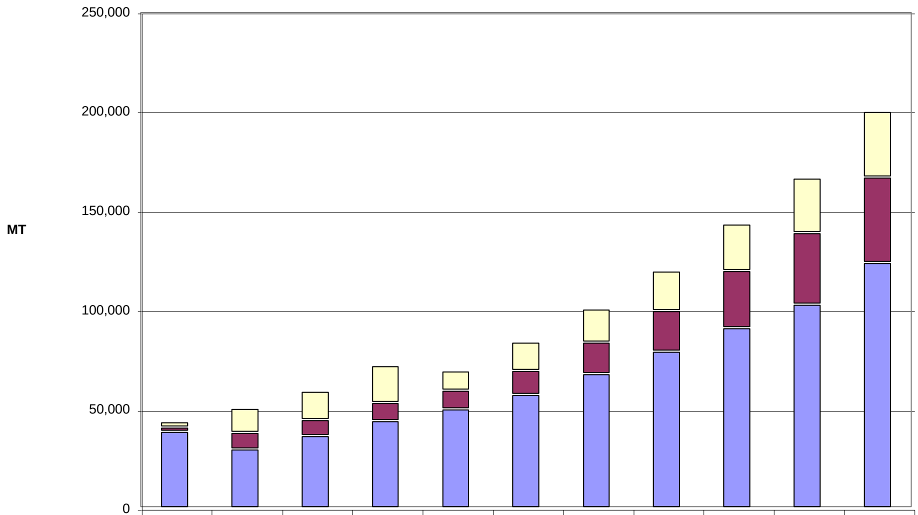
Figures 2 to 4 show the trend and distribution of the projected PM_{10}, SO_2, and NO_2 emissions given the generation mix and the existing and assumed pollution control measures under the base case scenario.



	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MINDANAO	11,436	52,898	64,237	81,173	41,397	59,113	68,372	78,719	88,105	102,100	110,330
VISAYAS	4,674	23,602	21,466	25,263	24,276	30,363	35,877	41,260	47,469	53,834	54,286
LUZON	171,272	74,210	93,662	123,516	152,191	197,564	259,996	320,976	371,479	423,016	473,291

Figure 2. Annual PM_{10} Emissions by Grid in 2000 and under the Base Case Scenario, 2000 – 2011

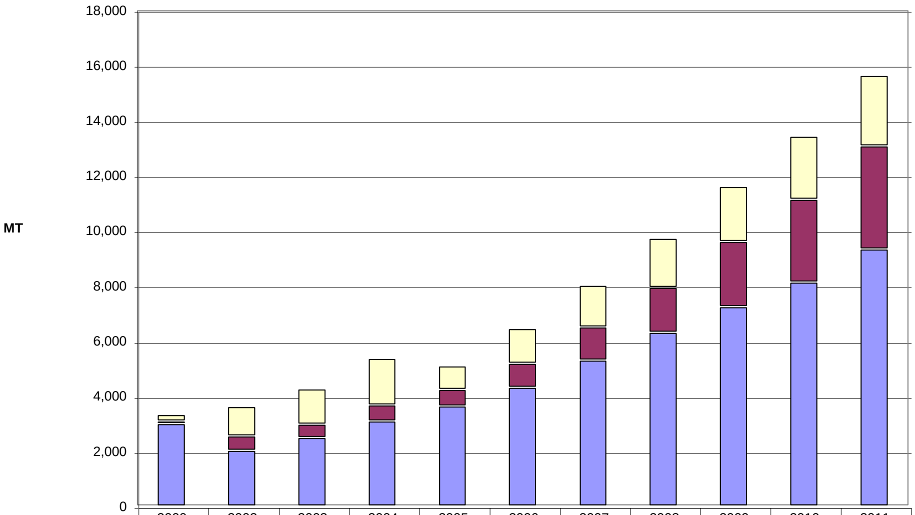
Note: MT is metric tonne



	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MINDANAO	2,500	11,942	14,304	18,749	9,544	14,156	16,832	19,939	23,316	27,417	32,941
VISAYAS	2,287	8,452	7,904	9,057	9,330	12,181	15,716	20,472	28,813	36,089	43,214
LUZON	38,459	29,677	36,490	43,897	49,977	57,054	67,585	78,826	90,667	102,530	123,515

Figure 3. Annual SO_2 Emissions by Grid: 2000 and 2002 – 2011 Base Case Scenario

Note: MT is metric tonne



	2000	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
MINDANAO	224	1,061	1,294	1,680	861	1,266	1,505	1,769	1,998	2,289	2,543
VISAYAS	101	523	470	571	599	864	1,189	1,624	2,374	3,017	3,733
LUZON	2,993	2,019	2,490	3,096	3,623	4,302	5,297	6,302	7,224	8,111	9,325

Figure 4. Annual NO_2 Emissions by Grid: 2000 and 2002 – 2011 Base Case Scenario

Note: MT is metric tonne

5.1.2 Changes in Spatial Pattern of Emissions

DOE projections indicate that power generation in Mindanao will not be sufficient to meet its growing demand starting 2005 while Visayas and Luzon will have surplus electricity supply. The completion of the interconnection plans linking the three main grids in 2005 is projected to facilitate the flow of surplus generation from Luzon and Visayas to Mindanao.

With the high indigenous scenario, Luzon will benefit from reduction in emissions, projected on the average at less than 1% for PM_{10} and NO_2 and 6% for SO_2 relative to the base case level (Table 12). It accounts for a substantial share in the incremental emission reductions, averaging 63% for PM_{10}, 87% for SO_2, and 67% for NO_2. Projected reductions in Luzon are matched by corresponding increases in Visayas and Mindanao, particularly in SO_2. On the average, Visayas is projected to generate incremental emissions by an average of 1% for PM_{10}, 6% for SO_2 and 3% for NO_2 relative to the base case levels particularly with the projected increased utilization of local coal and small oil-based generating units. Mindanao, on the other hand, is projected to generate an average incremental reduction by 1% in PM_{10} and 2% in NO_2 emissions while SO_2 emission is projected to slightly exceed the base case level with the projected operation of a new coal-fired power plant starting 2006.

Luzon, where most of the low-cost generating plants are located, is projected to remain as the major source of PM_{10}, SO_2 and NO_2 emissions despite the declining share in annual emissions (Figures 2 to 4). In 2000, Luzon accounted for 90%, 91%, and 89% of the total annual PM_{10}, SO_2, and NO_2 emissions, respectively (Tables 6 to 8).

Under the base case, Luzon's contribution to total emissions, on the average, is projected to decrease to 62% for PM_{10}, 69% for SO_2, and 64% for NO_2 or by 28%, 22%, and 25%, respectively relative to 2000 levels (Tables 6 to 8). Mindanao and Visayas are projected to correspondingly contribute an increasing share to total emissions with the commissioning of additional small-scale oil-based generating capacity between 2005 and 2010. Mindanao, on the average, will increase its share to 18-20% from 6-7% in 2000 while Visayas is projected to contribute 10-18% from 2-5% of total pollutant emissions in 2000.

Table 12. Geographic Distribution of Incremental Reduction in Emissions[1] under the High Indigenous Scenario: Philippines, 2002 - 2011

Grid	*2002*	*2005*	*2008*	*2011*	*Average*
PM_{10} (t)	*99*	*-1,655*	*-3,459*	*-8,414*	*-3,065*
LUZON	65 (0.3%)	-934 (7.2%)	-2,242 (0.1%)	-5,909 (11.7%)	-1,933 (-0.3%)
VISAYAS	26 (0.3%)	-118 (2.3%)	-501 (1.3%)	-1,763 (3.5%)	-544 (1.3%)
MINDANAO	8 (-0.6%)	-603 (-9.4%)	-716 (-1.4%)	-742 (7.8%)	-529 (-1.0%)
SO_2 (t)	*-1,097*	*-79,665*	*--140,346*	*-324,991*	*-128,612*
LUZON	-1,492 (0.6%)	-50,468 (3.8%)	-124,219 (7.3%)	-312,849 (22.3%)	-112,058 (-6.2%)
VISAYAS	1,132 (0.9%)	-1,426 (5.4%)	6,455 (6.5%)	11,384 (12.5%)	2,998 (5.8%)
MINDANAO	-737 (-0.2%)	-27,771 (9.1%)	-22,582 (0.8%)	-23,527 (9.5%)	-19,552 (0.4%)
NOx (t)	*1,032*	*-17,530*	*-34,300*	*-101,300*	*-33,855*
LUZON	699 (0.2%)	-10,287 (4.7%)	-22,742 (1.0%)	-72,628 (-8.4%)	-22,644 (0.0%)
VISAYAS	344 (0.3%)	-573 (3.5%)	-3,586 (3.0%)	-16,726 (5.9%)	-4,765 (2.6%)
MINDANAO	-8 (-0.5%)	-6,665 (-8.3%)	-7,972 (-2.4%)	-11,945 (4.3%)	-6,446 (-1.8%)

[1] Figures in parentheses represent percentage change relative to the base case

5.2 Potential Incremental Benefits of Operating Four Coal-fired Power Plants in Luzon

The study assessed the incremental benefits of operating four coal-fired power plants commissioned between 1996 and 2000 in Luzon under a high indigenous scenario. Modeling the changes in ambient concentrations of PM_{10}, SO_2 and NO_2, estimating the incremental health effects, and valuing these in economic terms estimated the incremental benefits. The study focused on adverse health effects, using dose-response functions established in other studies and economic values based on the benefit transfer technique.

The four coal-fired power plants owned and operated either by NPC or an IPP[8] together accounted for 30% of the total generating capacity in Luzon, 77% of the total coal-based capacity, and 22% of total generating capacity in the Philippines in 2000. The power plants have the following general characteristics: (1) 300 to 600 MW generating capacity per unit; (2) 150 to 220 meter stacks; (3) low NOx burners; (4) end-of pipe control equipments consisting mainly of electrostatic precipitators except one which also has a flue gas desulfurization system; and (5) imported coal with low ash and sulfur content fuel. Generation from these plants accounted for 44% of total electricity generated in Luzon, 80% of total coal-based generation, and 31% of total generation in 2000 (Table 13). Generating capacities of these plants are maximized under the two scenarios. Under the high indigenous scenario, average annual generation from the four power plants is projected at 17,631 GWh, 4% lower than the base case but 38% higher than the 2000 level.

5.2.1 Emissions and Predicted Ambient Concentrations

There is a wide variation in the estimated annual emissions[9] from the four coal-fired power plants. Under the high indigenous scenario, annual emissions range from about 22 t to 1,708 t for PM_{10}, 2,042 t to 35,431 t for SO_2, and about 2,686 t to 14,054 t for NO_2 or a total of 2,695 t PM_{10}, 50,584 t SO_2, and 30,350 t NO_2 (Table 13). These variations are explained by a number of factors such as location, plant characteristics, pollution control measures, and level of operations. Their aggregate emissions account for about 85% of total PM_{10}, 67% of NO_2 and 37% of SO_2 emissions in Luzon and slightly lower, 51%, 42% and 22%, respectively, relative to the country's total (Table 14). These emissions are 5% to 6% lower relative to the base case but are at least 50% higher than the 2000 emission levels since maximum capacity utilization are assumed (Table 13).

Two plants exceed the emission standards for PM_{10}, SO_2 and NO_2. One plant exceeds the ambient standard for SO_2. Table 15 shows the annual average emission rates, the corresponding maximum predicted ambient ground concentrations of PM_{10}, SO_2, and NO_2 within a 30-km radius from the plant, and the relevant emission and ambient standards. The emission standards for existing sources are 200 mg/Ncm for TSP and 1,500 mg/Ncm for SO_2 and NO_2. Stricter SO_2 and NO_2 standards are applied to new sources. For SO_2, the standard is 700 mg/Ncm. For NO_2, the standard distinguishes between coal and oil-fired power plants. Stricter emissions are applied to new oil-fired power plants - 500 mg/Ncm compared with 1,000 mg/Ncm for coal. The Clean Air Act (CAA) of 1999 also requires pollutant sources to install and operate continuous monitoring systems and Best Available Control Technology for each regulated pollutant with the potential to be emitted in quantities equal to or greater than 100 tonnes per year.

8 Confidential information is withheld as per agreement with data sources.
9 Emission estimates reflect controlled emissions.

Table 13 Average Generation and Annual Emissions of Four Coal-fired Power Plants in Luzon: 2000, Base Case and High Indigenous Scenario[1]

Scenario	*Annual Generation (GWh)*	*Annual Emissions (t)*		
		PM_{10}	*SO_2*	*NO_2*
2000 (actual)	12,750	1,472	33,622	18,748
1NLW	5,534	51	12,748	9,307
2NLWO	3,078	18	140	129
1SLWO	None	-	-	-
2SLWO	4,138	1,403	20,734	9,312
Base case	*18,409*	*2,857*	*53,650*	*32,009*
1NLW	7,688	43	10,760	7,855
2NLWO	3,812	953	2,111	5,932
1SLWO	2,729	25	2,707	3,120
2SLWO	4,180	1,836	38,072	15,102
High indigenous	17,631	2,695	50,584	30,350
1NLW	7,703	43	10,781	7,870
2NLWO	3,689	922	2,042	5,740
1SLWO	2,349	22	2,330	2,686
2SLWO	3,890	1,708	35,431	14,054

[1] Average generation covers the period 2002-2011 and were based on DOE projections. Power plants are identified here in terms of location, namely, northern (NL) or southern (SL) Luzon and in terms of type of EOP (end-of-pipe) control, that is, with (W) or without FGD (WO) since all of them have ESP and only one has an FGD.

Table 14. Relative Shares of Emissions from Four Coal-fired Power Plants in 2000 and under the Base Case and High Indigenous Scenario[1]

Scenario	*PM_{10}*		*SO_2*		*NO_2*	
	Phil.	*Luzon*	*Phil.*	*Luzon*	*Phil.*	*Luzon*
2000	44	49	18	20	43	49
Base case	34	55	14	20	29	46
High indigenous	51	85	22	37	42	67

[1] Percentage shares relative to total emissions from power generation in Luzon and in the Philippines are based on annual average for 2002-2011 emissions shown in Tables 9 and 10.

5.2.2 Potential Health Effects

Fifty-three municipalities with an estimated population of 1.75 million in 2000 are within a 30-km radius from the location of the four coal-fired power plants. Table 16 shows the estimated population at risk of exposure for years 2000 and 2011. The estimated population at risk within 30 km from each facility ranges from 154,618 to 591,577 in 2000 and 199,785 to 733,421 in 2011. Sixty percent of the population at risk is above 15 years old.

Table 15. Emission Rates and Maximum Predicted Ambient Ground Concentration within 30 km Radius: Four Coal-fired Power Plants, Luzon

	Emission Rate (mg/Ncm)[1]		
	PM_{10}	SO_2	NO_2
Emission standard (for fuel-burning equipt.)	50% of TSP std. –100	Existing – 1,500; New – 700	Existing – 1,500; New – 1,000
2000			
1NLW	na	na	na
2NLWO[2]	181.36	2,472.73	1,556.11
1SLWO	2.77	300.15	345.92
2SLWO[2]	138.59	2,873.44	1,139.77
	Max. Ambient Ground Conc. (µg/Ncm)[3]		
	PM_{10}	SO_2	NO_2
Ambient guideline[4]	Short-term[5] – 150 Long-term[6] - 60	ST – 180 LT – 80	ST - 150 LT – none
1NLW			
2000	22.20	22.20	20.35
Base case	22.19	9.63	19.50
High indigenous	22.23	9.65	19.54
2NLWO			
2000	53.05	35.81	15.65
Base case	53.36	41.02	23.08
High indigenous	51.64	39.70	22.34
1SLWO			
2000	Na	na	na
Base case	37.76	27.73	39.49
High indigenous	32.50	23.87	33.99
2SLWO			
2000	12.39	189.15	66.37
Base case	12.35	175.74	63.14
High indigenous	11.49	163.55	58.76

[1] Emission rates are based on 2000 data.

[2] For two units

[3] The predicted 24-hr annual average ground concentrations include ambient background concentration.

[4] Apply to source specific air pollutants from industrial sources/operations.

[5] Maximum limits represented by 98-percentile values not to exceed more than once a year. Averaging time is 24 hours

[6] Arithmetic mean

Table 16. Number of Municipalities and Estimated Population at Risk of Exposure Within 30 km Radius: Four Coal -fired Power Plants, 2000 and 2011

	1NLW	*2NLWO*	*1SLWO*	*2SLWO*	*Total*
Number of municipalities	19	6	16	12	53
Year/ Age Group					
2000	591,577	154,618	472,194	532,206	1,750,595
Below 15	39.5%	39.2%	40.0%	39.7%	694,717
Above 15	60.5%	60.8%	60.0%	60.3%	1,055,879
2011	684,240	199,785	649,027	733,421	2,266,473
Below 15	39.8%	39.2%	39.9%	39.7%	900,219
Above 15	60.2%	60.8%	60.1%	60.3%	1,366,254

The projected adverse health effects vary significantly among the four power plants. Under the high indigenous scenario, the projected total premature mortality outcomes associated mainly with changes in PM_{10} ambient concentrations range from 1,740 to 3,724 cases (Table 17). Projected cases of selected morbidity effects range from 129,126 to 499,041 cases for asthma, 34,735 to 135,008 cases for acute bronchitis, and 2,020 to 7,777 cases for chronic bronchitis. Appendices 6 and 7 provide a breakdown of the adverse health effects associated with each of the four power plants in 2000 and under the base case scenario, respectively. The projected incidence of adverse health effects from two coal-fired power plants in southern Luzon exceeds those from the two other coal-fired plants in the north. The difference is estimated to be much larger if the impact of a 600 MW coal-fired power plant utilizing local coal in southern Luzon[10] is included. The results support the use of area-based environmental standards espoused in the CAA, namely, less stringent standards for sources located in non-urban or non-industrialized areas and stringent standards for non-attainment areas – areas where specific pollutants have already exceeded ambient standards.

Under the high indigenous scenario, the average annual incidence of premature mortality is estimated at 982 cases while incidence of morbidity effects such as asthma, acute bronchitis and chronic bronchitis are 107,392, 28,893 and 1,680 cases respectively (Table 18). The total incremental benefit, measured in terms of reduction in adverse health effects, associated with operating the four power plants under the high indigenous scenario is negligible, an average of 0.03% relative to the base case (Table 19). Premature mortality is projected to decrease by six cases from 10,807 cases under the base case. Cases of selected morbidity effects are projected to decrease by 391 cases from 1,181,705 for asthma, by 5,209 from 317,926 for acute bronchitis, and by five from 18,484 for chronic bronchitis.

The projected incidence of adverse health effects under the high indigenous scenario exceeds the 2000 levels by about 78%. The marked increase in incidence of adverse health effects may be attributed to the significant increase in average annual emissions relative to the base case and the growth in population at risk. A significant share of the projected premature mortality and morbidity effects from the four coal-fired plants is associated with PM_{10} emissions (Table 18). For example, average premature mortality due to PM_{10} emissions is about 791 cases per year compared with 191 cases from SO_2 emissions under the high indigenous scenario.

[10] Please refer to another EEPSEA research report series prepared by Orbeta, et al (2000) for estimates.

Table 17. Premature Mortality and Morbidity Effects of Emissions from Four Coal-fired Power Plants in Luzon by Facility: High Indigenous Scenario, 2002-2011

Health Effect	*Incidence*[1]			
	1NLW	*2NLWO*	*1SLWO*	*2SLWO*
PM_{10}				
Mortality	2,475	1,601	3,677	951
Morbidity				
RHA	1,708	1,105	2,537	657
Emergency room visit	333,497	215,666	495,446	128,196
Restricted activity days	4,466,697	2,913,703	6,605,946	1,716,389
Acute bronchitis, children	90,361	57,716	135,008	34,735
Asthma attacks	335,917	217,230	499,041	129,126
Respiratory symptoms (RS)	20,647	13,349,855	30,755,453	7,950,779
Chronic bronchitis, adult	5,255	3,427	7,777	2,020
SO_2				
Mortality	3	139	47	1,908
Morbidity				
RS, children	5	319	108	4,425
RS, adult	4,017	152,898	89,674	3,722,263
NO_2				
RS, adult	259	25	190	651

[1] Unit is number of cases except for RAD and respiratory symptoms, which are reckoned in number of days.

Table 18. Average Annual Premature Mortality and Morbidity Effects of Emissions from Four Coal-fired Power Plants in Luzon: 2000, Base Case and High Indigenous Scenarios

Health Effect	*Incidence*[1]		
	2000	*Base Case*	*High Indigenous*
PM_{10}			
Mortality	445	791	791
Morbidity			
RHA	306	546	546
Emergency room visit	59,903	106,654	106,619
Restricted activity days	809,171	1,427,995	1,427,521
Acute bronchitis, children	16,147	28,902	28,893
Asthma attacks	60,336	107,428	107,392
Respiratory symptoms (RS)	3,712,142	4,736,445	4,734,249
Chronic bronchitis, adult	947	1,680	1,680
SO_2			
Mortality	159	191	191
Morbidity			
RS, children	395	443	442
RS, adult	320,949	361,743	360,805
NO_2			
RS, adult	278	103	102

[1] Unit is number of cases except for RAD and respiratory symptoms, which are reckoned in number of days.

Table 19. Incremental Health Effects of Emissions from Four Coal-fired Power Plants in Luzon Relative to the Base Case Scenario: 2002-2011

Health Effect	*Incidence*[1]			
	Base Case	*High Indigenous*	*Incremental Effect*	
			#	%
PM_{10}				
Mortality	8,706	8,704	-2	-0.02
Morbidity				
RHA	6,009	6,007	-2	-0.03
Emergency room visit	1,173,193	1,172,805	-388	-0.03
Restricted activity days	15,707,944	15,702,735	-5,209	-0.03
Acute bronchitis, children	317,926	317,820	-106	-0.03
Asthma attacks	1,181,705	1,181,314	-391	-0.03
Respiratory symptoms (RS)	52,100,899	52,076,734	-24,165	-0.05
Chronic bronchitis, adult	18,484	18,479	-5	-0.03
SO_2				
Mortality	2,101	2,097	-4	-0.19
Morbidity				
RS, children	4,870	4,857	-13	-0.27
RS, adult	3,979,173	3,968,852	-10,321	-0.26
NO_2				
RS, adult	1,128	1,125	-3	-0.27

[1]Unit is number of cases except for RAD and respiratory symptoms, which are reckoned in number of days.

5.2.3 Value of Health Effects

The incremental benefit associated with operating the four coal-fired power plants under the high indigenous scenario is estimated at Pesos 13 million (USD 492,126) in 1994 prices or 0.7% of the value of health damages under the base case (Table 15). The incremental benefit is measured in terms of the value of reductions in adverse health effects relative to the base case. Reduction in premature mortality is valued at Pesos 14 million (USD 529,982), 64% is associated with reductions in the ambient concentrations of SO_2.

Total health damage over the period 2002-2011 under the high indigenous scenario is valued at Pesos 19.2 billion [USD 726.8 million](discounted at 15% in constant 1994 prices), 84% of which is attributed to PM_{10} and 16% to SO_2 (Table 15). The value of premature mortality outcomes also largely attributed to PM_{10} accounts for 84% of the total. The value of chronic bronchitis among adults, also mainly due to PM_{10}, represent a significant share of the total value of morbidity effects – about 60% or Pesos 1.8 billion (USD 68.1 million). The relative share of the value of premature mortality and morbidity effects under the base case and the high indigenous scenario is similar to those in 2000 (Table 20).

Table 20. Value of Health Effects Associated with Pollutant Emissions from Four Coal-fired Power Plants in Luzon by Type: 2000, Base Case and High Indigenous Scenario (1994 Prices)

Health Effect	*Value (Million Pesos)*		
	2000	*Base case*[1]	*High Indigenous*
Total	2,887	19,181	19,168
Mortality	2,416	16,191	16,177
Morbidity	471	2,990	2,991
PM_{10}	2,355	16,032	16,027
Mortality	1,887	13,060	13,055
Morbidity	468	2,972	2,972
RHA	7	38	38
Emergency room visit	50	283	283
Restricted activity days	89	500	500
Acute bronchitis, children	6	38	38
Asthma attacks	3	18	18
Respiratory symptoms (RS)	58	331	331
Chronic bronchitis, adult	255	1,784	1,784
SO_2	532	3,148	3,140
Mortality	529	3,131	3,122
Morbidity	3	17	18
RS, children	-	-	-
RS, adult	3	17	18
NO_2	-	-	-
RS, adult	-	-	-

Note: "-" means value is negligible.

26.416 Pesos = 1 USD

[1] PV of total health benefits over the period 2001-2011 discounted at r=15% in 1994 prices

Under the high indigenous, health damages per plant ranges from Pesos 3.2 billion (USD 121.1 million) to Pesos 6.7 billion (USD 253.6 million), 0.02% to 0.12% relative to the base (Table 16). The values range from Pesos 1.7 billion (USD 64.4 million) to Pesos 6.7 billion (USD 253.6 million) for PM_{10} and Pesos 3 billion (USD 113.6 million) to Pesos 6.7 billion (USD 253.6 million) for SO_2. The incremental benefit relative to the base ranges from negligible to 0.07% for PM_{10} and 0.1% to 25% for SO_2 (Table 21 and Appendix 8). The value of health damages in 2000 was about Pesos 2.9 billion (USD 109.8 million), 82% of which is associated with PM_{10}. Values range from Pesos 558 million (USD 21.2 million) to Pesos 862 million (USD 32.6 million) broken.

The damage estimate far outweighs the cost of shifting to cleaner fuel estimated at Pesos 0.034 (USD 0.001) /kWh[11] (Orbeta *et al.* 2000). The value of health damages per unit of electricity generated range from Pesos 0.060 (USD 0.002) to Pesos 0.289 (USD 0.011) per kWh or an average of Pesos 0.109 (USD 0.004)/kWh under the high

[11] Value is based on results of an EEPSEA study on the benefits and cost of controlling pollution from fossil-fired power plants in Region IV in Luzon. Shift to cleaner fuel entail a reduction from 3% to 2% sulfur content and from 21% to 12% ash content.

indigenous scenario (Table 16). It would therefore be more beneficial to utilize cleaner fuel or implement other measures to control emissions from coal-fired power generation in Luzon.

Table 21. Value of Health Effects of PM_{10}, SO_2 and NO_2 Emissions from Four Coal-fired Power Plants in Luzon by Plant: 2000, Base Case and High Indigenous Scenarios (1994 Prices)

Plant/ Scenario	*Value of Health Effects*					
	Value (Million Pesos)			*Per Megawatt-hour (Pesos)*		
	2000	*Base Case*[1]	*High Ind.*	*2000*	*Base Case*	*High Ind.*
Total/Average	2,887	19,181	19,168	210	104	109
1NLW	862	4,619	4,618	171	60	60
2NLWO	558	3,161	3,160	180	83	86
1SLWO	681	6,800	6,792	464	249	289
2SLWO	786	4,601	4,598	190	110	118
PM_{10}	2,355	16,034	16,029	218	*106*	*118*
1NLW	861	4,615	4,615	170	60	60
2NLWO	521	2,952	2,952	168	77	80
1SLWO	675	6,727	6,722	460	246	286
2SLWO	297	1,740	1,740	72	42	45
SO_2	532	3,147	3,139	33	*19*	*20*
1NLW	0.9	4	3	-	-	-
2NLWO	37	209	209	12	5	6
1SLWO	6	73	69	4	3	3
2SLWO	488	2,861	2,858	118	68	73

[1] PV of total health benefits over the period 2002-2011 discounted at r=15% in 1994 prices

Note: 26.416 Pesos = 1 USD

6.0 CONCLUSION AND RECOMMENDATIONS

This study showed that increased use of indigenous energy resources, except local coal, for power generation would reduce the air quality impacts and the associated adverse health effects, particularly in Luzon.

A rapid assessment of the incremental levels of PM_{10}, SO_2 and NO_2 emissions from all power plants connected to the main grid in the Philippines during the 2002-2011 planning period indicated that a high indigenous scenario - a scenario that favors greater use of indigenous energy resources - except local coal which is relatively dirty, would generate significant incremental reductions in pollutant emissions relative to the base case or the business as usual scenario.

Using a damage function approach, the study also showed that operating four coal-fired power plants commissioned between 1996 and 2000 in Luzon under a high indigenous scenario would still generate incremental benefits expressed in terms of the value of the reductions in adverse health effects relative to the base case. The four power plants accounted for over 40% of PM_{10} and NO_2 emissions from power generation in Luzon and in the country as a whole in 2000. Modeling the changes in ambient concentrations of PM_{10}, SO_2 and NO_2, determining the incremental health effects, and valuing these in economic terms estimated the incremental benefits. The study focused on adverse health effects using dose-response function established in other studies and economic values based on the benefit transfer technique. The impact area was limited to a 30-km radius from the location of each plant. Total population at risk was estimated at 1.75 million in 2000 and 2.27 million by 2011 spread over 53 municipalities.

The major findings and recommendations of the study include the following:

1. A high indigenous scenario is associated with significant improvement in air quality relative to the base case, particularly in Luzon during the period studied. Average incremental emission reduction from power generation is largest for SO_2, 128,840 t or 41% annually relative to the base case compared with 38% (5,237 t) for PM_{10} and 34% (34,647 t) for NO_2. Projected improvements in air quality may be attributed to the government's policies to boost the development and utilization of indigenous renewable energy resources such as natural gas, reduce dependence on imported fuel for electric generation with explicit plans to retire old oil-based and coal-fired generating capacities.

2. There is a significant increase in the average annual emissions under the high indigenous scenario relative to 2000 levels. Projected estimates are higher by 58% for PM_{10}, 23% for SO_2 and 67% for NO_2 as generating capacities, particularly coal-based capacities, are maximized with additional coal and oil-based capacities to meet a growing demand. These increments, nonetheless, are lower by 95%, 85%, and 84%, respectively compared to the percentage increase under the base case.

3. The increased use of local coal, which is relatively dirty compared to imported coal, is projected to generate an incremental increase in average annual emissions relative to the base posing harm on the environment. Average incremental increase in emissions is estimated at 167 t for PM_{10}, 9,767 t for SO_2, and 3,701 t for NO_2 annually.

4. Luzon, under the high indigenous scenario, will benefit from reductions in annual emissions from power generation projected on the average at less than 1% for PM_{10} and NO_2 and 6% for SO_2 relative to the base case. It accounts for a substantial share in the incremental emission reductions, averaging 63% for PM_{10}, 87% for SO_2, and 67% for NO_2. Luzon, where most of the low-cost generating plants are located, however, is projected to remain as the major source of PM_{10}, SO_2 and NO_2 emissions despite the declining share in annual emissions.

5. Visayas and Mindanao is projected to match the projected emission reduction in Luzon with incremental increases in emissions, particularly SO_2 under the high indigenous scenario. Visayas is projected, on the average, to generate a 6% incremental increase in SO_2 emissions, 1% for PM_{10}, and 3% for NO_2 with the projected increased utilization of local coal and small oil-based generating units. Mindanao is projected to slightly exceed its base case level for SO_2 emission with the projected operation of a new coal-fired power plant starting 2006.

6. Assessment of the physical impacts of four coal-fired power plants in Luzon indicated wide variations in the level of associated adverse health effects. Under the high indigenous scenario, projected total premature mortality outcomes range from

1,740 to 3,724 cases mainly associated with changes in PM_{10} ambient concentrations. Projected cases of selected morbidity effects range from 129,126 to 499,041 cases for asthma, 34,735 to 135,008 cases for acute bronchitis and 2,020 to 7,777 cases for chronic bronchitis. The projected incidence of adverse health effects of coal-fired power plants in southern Luzon is greater than those in the north. These variations are explained by a number of factors affecting the level of emissions such as location, plant characteristics, pollution control measures, level of operations, background concentration of pollutants and the size of population at risk. The results support the use of area-based instead of uniform environmental standards as envisioned by the Clean Air Act. The study recommends an assessment of the Clean Air Act and its implementing rules and regulations to make it more responsive to the needs of a more competitive power sector.

7. Under the high indigenous scenario, average incidence of premature mortality is estimated at 982 cases annually while incidence of morbidity effects such as asthma, acute bronchitis, and chronic bronchitis are 107,392, 28,893 and 1,680 cases respectively. The total incremental benefit, measured in terms of the reduction in adverse health effects associated with operating the four power plants is negligible, an average of 0.03% relative to the base case. The projected estimate under the high indigenous scenario, however, is 78% higher relative to the 2000 estimated levels. The marked increase may be attributed to the significant increase in emissions and the growth in population at risk. A significant share of adverse health effects is associated with PM_{10} emissions.

8. Total health damage associated with PM_{10}, SO_2 and NO_2 emissions from the four coal-fired power plants is valued at Pesos 19.2 billion (USD 726.8 million) over 2002-2011 under the high indigenous scenario. The values range from Pesos 3.2 billion (USD 121.1 million) to Pesos 6.7 billion (USD 253.6 million) per plant. The value of premature mortality cases due mainly to PM_{10} emissions accounts for 84% of the total. The total incremental benefit is about Pesos 13 million [USD 492,126] (1994 prices) or 0.07% of the value of projected health damages under the base case. Reduction in premature mortality is valued at Pesos 14 million (USD 529,982), associated mainly with improvements in SO_2 ambient concentrations. Incremental benefit ranges from Pesos 1 million (USD 37,856) to Pesos 8 million (USD 302,847) per plant or 0.02% to 0.12% relative to the base.

9. The health damage estimates ranging from Pesos 0.060 (USD 0.002) to Pesos 0.289 (USD 0.011) per kWh or an average of Pesos 0.109 (USD 0.004)/kWh under the high indigenous scenario far outweighs the cost of shifting to cleaner fuel estimated at Pesos 0.034 (USD 0.001)/kWh (1994 prices).

10. Both the base case scenario and the high indigenous scenario involve increases of nearly 10% a year in power generation and significant increases in emissions and health damages. In both scenarios, emissions will be markedly higher in 2011 than in 2000. For example, even in the high indigenous scenario, emissions of PM_{10} will be 117% higher in 2011 than they were in 2000.

Since even the most favorable scenario assessed here will result in significant increases in emissions, we recommend that: (a) incremental emission monitoring and control efforts by government and generating firms be geared at PM_{10} and SO_2 emissions in Luzon; (b) existing policies on the use of local coal for power generation be reviewed;

(c) a review of the Clean Air Act and its implementing rules and regulations be made to make it more responsive to the needs of a more competitive power sector; and (d) policies to encourage energy conservation should also be pursued.

REFERENCES

Burtraw, D.; K. Palmer; and M. Heintzelman 2000. Electricity Restructuring: Consequences and Opportunities for the Environment. Resources for the Future discussion paper 00-39.

Congressional Research Service. 1998. Environmental Issues-Electric Utility Restructuring, *In* the National Library for the Environment, Library of Congress CNIE website.

DOE (Department of Energy). 2001. Philippine Energy Plan (2002-2011). DOE. Metro Manila, Philippines.

Environmental Impact Assessment (EIA).

Hagler Bailly. 1998. The Environmental Implications of Power Sector Reform in Developing Countries. A Report for the Office of Energy, Environment and Technology. USAID Report No. 98-05 March 1998. Arlington, VA, USA.

NPC (National Power Corporation). 2000. 2000 Power Development Program. NPC. Metro Manila, Philippines.

National Statistical Coordination Board. 2001. 2000 Philippine Statistical Yearbook. NSCB. Metro Manila, Philippines.

National Statistics Office. 1990 and 1995 Census of Population and Housing. NSO. Metro Manila, Philippines.

Ostro, B. 1994. Air Pollution and Mortality: Results from Santiago, Chile. World Bank, Washington D.C.

_______. 1996. A Methodology for Estimating Air Pollution Health Effects. World Health Organization. Geneva.

Orbeta, E. M.; C. M. Rufo and A. L. Indab. 2000. Benefits and Costs of Controlling Emissions from Fossil-fired Power Plants: Region IV, Philippines. EEPSEA Research Report Series.

PAGASA 2000. Meteorological data.

Palmer, K. and D. Burtraw 1996. Electricity Restructuring and Regional Air Pollution. Resources for the Future (July) discussion paper 96-17-REV2.

Rowe, R.D.; C.M. Lang; L.G. Chestnut; D.A. Latimer; D.A. Rae; S.M. Bernow; and D.E. White. 1995. New York State Environmental Externalities Cost Study (Volume I). ESEERCO, New York.

Tietenberg, Tom. 1996. Environmental and Natural Resource Economics (Fourth edition). Harper Collins Publishers, Inc., New York.

U.S. Environmental Protection Agency. 1995. AP-42.

U.S. Environmental Protection Agency. 1997. The Benefits and Costs of the Clean Air Act, 1970 to 1990. U.S. EPA. Washington, D.C., USA.

World Bank. 1997. Philippine Energy Strategy and Pricing Study. Washington D.C.

ACRONYMS

ADB	Asian Development Bank
CAA	Clean Air Act
COI	Cost of Illness
DENR	Department of Environment and Natural Resources
DOE	Department of Energy
EIA	Environmental Impact Assessment
EMB	Environmental Management Bureau
EPIRA	Electric Power Industry Reform Act
ESP	Electrostatic precipitators
GDP	Gross Domestic Product
IPPs	Independent Power Producers
kWh	kilowatt hours
mg/Ncm	milligram per normal cubic meter
μg/Ncm	microgram per normal cubic meter
MERALCO	Manila Electric Company
MW	megawatt
NAMRIA	National Mapping and Resource Information Authority
NEDA	National Economic and Development Authority
NO_2	nitrogen dioxide
NPC	National Power Corporation
NSCB	National Statistical Coordination Bureau
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PDP	Power Development Plan
PEP	Philippine Energy Plan
PM_{10}	particulate matter equal or less than 10 microns in diameter

PSALM Corp.	Power Sector Assets and Liabilities Management Corporation
REECS	Resources, Environment and Economic Center for Studies, Inc.
RHA	Respiratory Hospital Admission
RS	Respiratory symptoms
SO_2	sulfur dioxide
t	metric tonne or tonne
TRANSCO	Transmission Commission
TSP	Total Suspended Particulates
TWh	tegawatt hours
US-EPA	United States – Environmental Protection Agency
WB	World Bank
WHO	World Health Organization
WTP	Willingness to Pay

APPENDICES

APPENDIX 1

Profile of Fossil-fired Power Plants Connected to the Main Grid: Philippines, 2000

Plant Code	*Plant Type*	*Grid*	*Rated Capacity (MW)*[1]	*Year Commissioned*	*Proj. Life*	*Ownership*	*Stack Height (m)*	*Pollution Control Equipt.*
LCCNG[2]	CC/NG	Luzon	1,040	2000		IPP		
LC1	Coal	Luzon	300	1984	28	NPC	120	ESP
LC2	Coal	Luzon	300	1995	41	NPC	150	ESP
LC3	Coal	Luzon	300	1998	30	NPC	150	ESP & Low NOx burners
LC4	Coal	Luzon	300	1998	30	NPC	150	ESP & Low NOx burners
LC5	Coal	Luzon	470	2000	30	IPP	150	ESP & Low NOx burners
LC6	Coal	Luzon	350	1996	31	IPP	200	ESP & Low NOx burners
LC7	Coal	Luzon	350	1996	31	IPP	200	ESP & Low NOx burners
LC8	Coal	Luzon	500	1999	25	IPP	220	ESP, FGD & Low NOx burners
LC10	Coal	Luzon	500	1999	25	IPP	220	ESP, FGD & Low NOx burners
LOBCC	OB-CC	Luzon	620	1993; 1994	20	NPC-IPP	25	
LOBD1	OB-D	Luzon	215	1994-95	16	IPP	40	
LOBD2	OB-D	Luzon	108	1994	15	IPP	50	
LOBD3	OB-D	Luzon	48	1995	10	IPP		
LOBD4	OB-D	Luzon	58	1994-95	5	IPP		
LOBD5	OB-D	Luzon	105	1993	21	IPP		
LOBD6	OB-D	Luzon	217	1995; 2000	12	MECO-IPP		
LOBGT	OB-GT	Luzon	121	1990-91; 1993	13	IPP		
LOBT1	OB-OT	Luzon	300	1975	35	NPC-IPP	90	multicyclones
LOBT2	OB-OT	Luzon	350	1979	35	NPC-IPP	90	multicyclones
LOBT3	OB-OT	Luzon	200	1970	30	NPC	207	multicyclones
LOBT3	OB-OT	Luzon	200	1971	30	NPC	212	multicyclones
MNRES	NRES	Mindanao	8	1995	25	IPP		
MOBD1	OB-D	Mindanao	100	1997	20	IPP	40	
MOBD2	OB-D	Mindanao	100	1994	19	NPC-IPP	45	
MOBD3	OB-D	Mindanao	100	1994	19	NPC-IPP	45	
MOBD4	OB-D	Mindanao	98	1993	21	IPP		
MOBD5	OB-D	Mindanao	50	1998	21	IPP		
VC1	Coal	Visayas	55	1986	25	NPC-IPP	25	
VC2	Coal	Visayas	50	1981	30	NPC-IPP		
VC3	Coal (FB)	Visayas	55	1993	30	IPP	80	baghouse; wet scrubber
VOBD	OB-D	Visayas	44	1993	15	IPP	50	
VOBD	OB-D	Visayas	75	1997	15		50	
VOBD	OB-D	Visayas	33	1997			80	baghouse; wet scrubber
VOBD	OB-D	Visayas	22	1978; 1986; 1996	23	NPC		
VOBD	OB-D	Visayas	32	1985	20	NPC		
VOBD	OB-D	Visayas	32	1985	20	NPC		
VOBD	OB-D	Visayas	32	1981	24	NPC		
VOBD	OB-D	Visayas	37	1979-83; 1999	20	NPC		
VOBGT1	OB-GT	Visayas	55	1991		NPC-IPP		
VOBGT2	OB-GT	Visayas	1	1995		NPC		

Sources: NPC. 2000. Year 2000 annual Report; EIA of power plants

[1] For IPP, contracted capacity.

[2] A CCGT PP commissioned late 2000 is fueled with diesel until 2001 and with natural gas starting 2002.

APPENDIX 2

Emission Coefficients[1] (lb/MMBTU)

Type of Power Plant	*PM_{10}*	*SO_2*	*NOx*
Coal thermal (lb/tonne)	2.3A[2]	38S[3]	14.4
Diesel	0.057	1.01S	3.2
Oil thermal	0.011A	1.047S	0.173
Gas turbine	0.061	1.01S	0.698
Combined CCGT			
Natural gas-fired	0.007	0.0006	0.13
Distillate-fired	0.061	1.01S	0.698
Natural gas	0.007	0.0006	0.13

Reference: www.epa.gov/ttn/chief/ap42

Notes:

[1] Emission coefficients shown are uncontrolled. Actual coefficients used reflect existing control. The assumed efficiencies of end-of-pipe pollution control equipments are as follows: For PM: multicyclones – 80%, ESP – 99.2%, baghouse – 99.8%. For SOx, wet scrubber or FGD – 90%, for NOx, low NOx burner – 45%, selective catalytic reduction with water injection – 78%.

[2] A = ash weight percent in fuel; range from 3 to 12%.

[3] S = sulfur content in fuel

APPENDIX 3

Dose-Response Coefficients used to Estimate Annual Health Effects (per µg/m^3 Change in PM_{10}, SO_2 and NO_2 Ambient Concentration)

Health Effect	*Unit*	*Coefficient*[1]
PM_{10}		
Mortality	% increase in cases	2.70E-01
Morbidity		
Respiratory hospital admissions (RHA)	Cases	1.20E-05
Emergency room visit (ERV)	Cases	2.36E-03
Restricted activity day (RAD)	Cases/ adult>15	5.75E-02
Acute bronchitis, children	Cases/child<15	1.60E-03
Asthma attacks (AA)	Cases/Asthmatic	5.90E-02
Respiratory symptoms	Cases	1.80E-01
Chronic bronchitis, adult	Cases/adult>15	6.12E-05
SO_2		
Mortality	% increase in cases	4.80E-02
Respiratory symptoms (RS), children	Prob. of cough/child	1.81E-05
RS/chest discomfort, adult	Prob. of chest discomfort/adult	1.00E-02
NO_2 (per ppm)		
Respiratory symptoms, adults	Cases	1.00E-02

Source: Ostro 1994 and 1996

Note: [1] Central estimate

APPENDIX 4

Unit Values for Mortality and Morbidity Effects

Health Effect	*Value per Case (1994 Pesos)*[1]			*Type of Estimate*
	Low	*Central*	*High*	
Mortality (all causes)	1,584,295	3,075,400	6,150,790	WTP
Morbidity				
Respiratory hospital admissions (RHA)	6,525	13,050	19,570	Adjusted COI
Emergency room visits (ERV)	250	495	740	Adjusted COI
Child bronchitis	130	250	380	Adjusted COI
Restricted activity day (RAD)	35	65	100	WTP & Adj. COI
Asthma attack day	10	30	50	WTP
Acute resp. symptom day	5	10	15	WTP
Adult chronic bronchitis	117,420	195,710	313,130	WTP

[1] Adjusted from the original values reported in Rowe et al. (1995) for differences in income levels and exchange rates. Values were rounded to the nearest ten.

Note: 26.416 Pesos = 1 USD

APPENDIX 5

Incremental Projected Generation[1] under the High Indigenous Scenario by Type and by Grid: Philippines, 2002-2011

Type	*Incremental Generation (GWh)*			
	2002	*2005*	*2008*	*2011*
Coal	-9	-1,077	2,614	2,776
Local	368	924	2,695	4,343
Imported	-377	-2,002	-81	-1,569
Oil-based	-345	-3,108	-4,401	-543
Diesel	-53	-368	-3,542	-491
Fuel-oil	-292	-2,739	-859	-52
Natural gas	0	2,205	8,025	30,290
Hydropower	130	667	1,908	2,968
Geothermal	277	1,787	2,425	4,197
NRE	0	257	517	927
Others	0	-74	-11,199	-42,366
Baseload	0	-6	-10,090	-35,651
Midrange	0	-71	-967	-4,993
Peaking	0	-3	-142	-1,722
TOTAL	53	657	-111	-1,751
LUZON	109	157	-2,335	-2,469
VISAYAS	-61	1,326	2,077	1,243
MINDANAO	5	-826	147	-525

[1] Relative to the base case

APPENDIX 6

Health Effects of Pollutant Emissions from Four Coal-fired Power Plants: Luzon, 2000

Health Effect	*Incidence (# cases)*[1]			
	1NLW	*2NLWO*	*1SLWO*[2]	*2SLWO*
PM_{10}				
Mortality	228	138		79
Morbidity				
RHA	157	95		54
Emergency room visit	30,705	18,585		10,613
Restricted activity days	414,226	252,199		142,746
Acute bronchitis, children	8,292	4,976		2,879
Asthma attacks	30,927	18,719		10,690
Respiratory symptoms (RS)	1,903,319	1,150,544		658,279
Chronic bronchitis, adult	485	295		167
SO_2				
Mortality	0	12		157.8
Morbidity				
RS, children	1	27		367
RS, adult	531	12,557		307,861
NO_2				
RS, adult	24	2		54

[1]Unit is number of cases except for RAD and respiratory symptoms, which are reckoned in number of days.

[2] No health effects were estimated since the plant did not report any generation in 2000.

APPENDIX 7

Health Effects of Emissions from Four Coal-fired Power Plants in Luzon: Base Case, 2002-2011

Health Effect	*Incidence (# cases)*[1]			
	1NLW	*2NLWO*	*1SLWO*	*2SLWO*
PM_{10}				
Mortality	2,475	1,601	3,679	951
Morbidity				
RHA	1,708	1,105	2,539	657
Emergency room visit	333,497	215,747	495,753	128,196
Restricted activity days	4,466,705	2,914,804	6,610,043	1,716,392
Acute bronchitis, children	90,361	57,738	135,092	34,735
Asthma attacks	335,917	217,312	499,350	129,126
Respiratory symptoms (RS)	20,684	13,354,917	30,774,506	7,950,792
Chronic bronchitis, adult	5,255	3,427	7,782	2,020
SO_2				
Mortality	3	139	49	1,910
Morbidity				
RS, children	7	319	114	4,430
RS, adult	5,777	153,049	94,323	3,726,024
NO_2				
RS, adult	259	25	193	651

[1]Unit is number of cases except for RAD and respiratory symptoms, which are reckoned in number of days.

APPENDIX 8

Present Value of Health Effects of Pollutant Emissions from Four Coal-fired Power Plants in Luzon: Base Case (1994 Prices)

Health Effect	*PV of Health Effects (Million Pesos)*				
	1NLW	*2NLWO*	*1SLWO*	*2SLWO*	*Total*
Total	4,619	3,161	6,800	4,601	19,181
PM_{10}	4,615	2,952	6,727	1,740	16,032
Mortality	3,759	2,402	5,482	1,417	13,060
Morbidity	856	550	1,245	323	2,972
RHA	11	7	16	4	38
Emergency room visit	81	52	119	31	283
Restricted activity days	144	93	209	54	500
Acute bronchitis, children	11	7	16	4	38
Asthma attacks	5	3	8	2	18
Respiratory symptoms (RS)	95	61	139	36	331
Chronic bronchitis, adult	508	327	738	191	1,764
SO_2	5	209	73	2,861	3,148
Mortality	5	209	73	2,844	3,131
Morbidity	-	-	-	17	17
RS, children	-	-	-	-	-
RS, adult	-	-	-	17	17
NO_2					-
RS, adults	-	-	-	-	-

Note: - indicates value is negligible

26.416 Pesos = 1 USD